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China's wind, biomass and solar power generation: What the situation tells us?

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ABSTRACT

As the largest developing country, China has abundant wind, biomass and solar energy resources. Under the large demand for electricity and the shortage of fossil energy, it is essential to develop renewable energy generation in China. This paper analyzes the resources, scale, market operation, profitability and policies of China's wind, biomass and solar power generation and gives a discussion of the investment risks in the current situation. It is expected that the analysis in this paper could be helpful for the potential investors to make decision.

Contents

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1. Introduction

As global issues, such as climate change, energy security and ecological environment deterioration becoming increasingly serious, the utilization of biomass, wind and solar energy is significant. Countries all over the world are adopting common strategy of developing renewable energy and more than 50 countries have enacted policies and regulations for renewable energy development. The share of global renewable energy power generation market continuously grows, investment increases significantly and increasing number of big business enter into this field. Large-scale exploitation and utilization of renewable energy sources have become major trend for the world's future energy strategy.

As one of the largest energy consumption countries, China is facing with increasing pressures from economic, social, environmental and sustainable development. Vigorously developing renewable power generation effectively fits the inner reality demand of China's economic and social development. Since the implementation of Renewable Energy Law in 2006, China renewable energy industry has entered a period of rapid development. "We do not hesitate to reduce the speed of GDP growth as price to achieve the goal of energy-saving and emission-reduction" said Premier Wen Jiabao in UN conference of climate change in Cancun. And according to the goal of China's 2020 renewable energy development, the consumption of non-fossil energy will account for 15% of primary energy consumption. China has abundant biomass, wind and solar energy resources. Therefore, the development of renewable energy such as biomass, wind and solar power generation and increasing investments in renewable energy will be the trend of China's economy.

2. Current situation

The Chinese renewable energy market had achieved revenue of $20.5 billion in 2010, representing a compound annual rate of change (CARC) of −1.7% for the period spanning 2006–2010.Until 2010, the grid feed-in installed capacity of China's wind, solar and biomass energy reached 36.7 million kW, increased about 65%, and accounted for 4% of all the installed capacity. Installed capacity of grid feed-in wind power was 31.31 million kW, accounted for about 85.3%; installed capacity of grid-connected solar PV was 400,000 kW; biomass and other power generation capacity was about 5 million kW (Fig. 1).

In 2010, the generating capacity of China's renewable energy reached about 78.2 billion kW h and generating capacity from wind power was 50.1 billion kW h, accounting for 64.1% of all the renewable energy generation; solar power generated about 600 million kW h, representing about 0.8%; 27.5 billion kW h came from biomass and other energy, rating for 35.1% (Fig. 2). Through the comparison of the two charts we know that installed capacity of grid feed-in wind power accounts for 85.3% but its generating capacity only accounts for 64.1%. There are some grid feed-in problems of wind power generation, which leads to low equipment utilization. But the proportion of generating capacity of biomass power generation is higher than the proportion of its installed capacity which shows that biomass power is more stable than others.

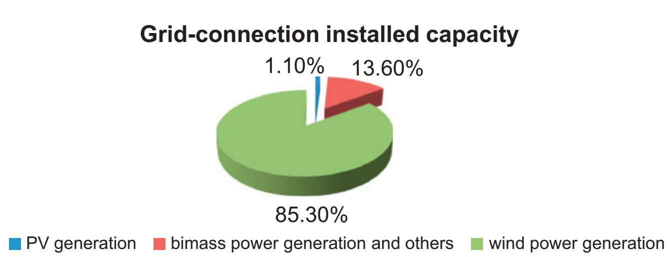


Fig. 1. Installed capacity constitutes of China's grid feed-in renewable energy in 2010.

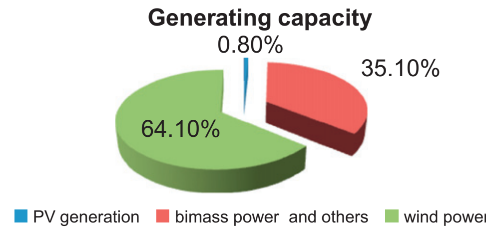


Fig. 2. Constitutes of renewable energy generation in 2010.

2.1. Biomass power generation

Industrialized production of biomass power generation in China started from 2004. And with the support of national feed-in tariff and tax incentives, China's biomass power industry had made significant progress during the year from 2007 to 2009. Until 2008, more than 100 biomass power projects were approved by national and provincial Development and Reform Commission and total installed capacity of these projects was 3.15 million kW. China has basically mastered technologies of agricultural and forest residues power generation, municipal solid waste generation, dense biomass fuel power generation etc.

Up to the end of 2010, 25 provinces or districts had invested in biomass power projects. For the effect of resource factors and regions' characteristics, regional distribution of biomass power generation was more distinctly. Biomass power generation was mainly concentrated in East China (Jiangsu, Zhejiang, Anhui, Jiangxi, Fujian and Shanghai), where Jiangsu's biomass power installed capacity ranked first, reaching 439,800 kW, Henan following behind. Until 2010, the installed capacity of national biomass power generation was about 5.5 million kW, dominated by bagasse power generation and waste generation.

But problems such as outdated generation technology, high raw material costs and its collection, storage, transportation still hinder the development of China biomass power generation.

2.2. Wind power generation

With the support of effective policy, excluding Taiwan Province, China's new installed capacity reached 18.93 GW in 2010, accounting for 48% of the world's new market, and the cumulative installed capacity was beyond United States, becoming first in the world. In 2010, national wind electricity generation was 50.1 billion kW h and wind power construction investment was $ 89.1 billion, an increase of 13.9%, and the cumulative wind power installed capacity reached 44.73 GW. Calculated in accordance with the national wind power installed capacity of 1 GB developed installed capacity was less than 5% of potential capacity. The cumulative installed capacity of 7 –10 million kW-level large wind power base, which were planned by Chinese government, was less than 200 GW, accounting for only 20%. This shows that the development potential for wind energy in China is enormous.

Wind farms exit in 29 provinces, municipalities (excluding Hong Kong, Macao, Taiwan) in China and there are seven provinces with installed capacity of more than 2 GW. Among them, Inner Mongolia autonomous region has the largest installed capacity of 13.86 GW, followed by Gansu, Hebei and Liaoning province. The reverse distribution of China's wind energy resource and load center indicates that China must establish a large-capacity, long-range energy transmission channel and a nationwide clean energy configurations and absorption. Wind power in three North region (Northeast and North China,

Northwest) need to be absorbed in the national wide and the main absorption regions are North China, East China and central China. Flow direction of wind power is similarly with energy flow and they both present the pattern of power from west to east and power from north to south. Large wind power base exists "into parts" "spin-off examination and approval" phenomenon, wind power sent out and absorption caused difficulties. The lag of power grid construction becomes bottleneck of wind power development and leads to problems in the transportation and absorption of wind power.

2.3. Solar PV power generation

In the 1980s, China introduced production line of sets of battery/component and amorphous silicon solar cells, which initially formed the solar PV industry in China. At the end of 1990s, a number of component packaging plants were built all over China. Nowadays, besides the use for remote regions' power supply and distributed power supply such as communications, navigation and traffic, China has started the testing and demonstration work of roof grid-connected PV power system, as well as the feasibility study for the massive desert grid-connected PV system. And China also opened the application market of large solar power generation, distributed grid-connected PV generation and grid-off PV generation.

In 2010, the production of solar module in China was up to 10 GW, accounting for 45% of the world's production, but the production of thin-film cells was still small and industrialization technology of silicon-based thin-film batteries was not mature. The newly installed capacity of solar PV in China was 500 MW in 2010, accumulated to 900 MW, ranking the top 10 all over the world and the investment in terrestrial photovoltaic power plant was over $ 1 billion. Driven by market demand, the scale of China's PV industry chain had been formed. Both for equipment and supportive materials' manufacture, localization process was accelerating. In addition, China had mastered key technologies in all aspects of the industry chain. Until now, there exist 20–30 polysilicon manufacturers, more than 60 wafer enterprises, over 60 battery businesses and above 330 component companies. There are 30 listed companies in the solar PV industry and total output value are beyond $ 300 billion with 300 thousand employee as well as $ 22 billion of import and export value.

Solar power also faces many problems. First, high cost is the main factor that restricts scale development of solar power. And second, grid feed-in and operation management are the key factors which limit the development of distributed PV power generation.

3. Comparison: Biomass, wind and solar energy generation

3.1. Resources

3.1.1. Total resources

Biomass energy resources in China are abundant, various, widely distributed and large output. Biomass resources cover waste of agricultural, forestry, industrial, animal and sewage as well as energy crops. The total amount of biomass resources in China is about 650 million tonnes coal equivalent, of which the amount of annual agricultural waste is 308 million tonnes coal equivalent and the annual fuel wood is 130 million tonnes coal equivalent (see Table 1).

With vast land and long coastline, China is rich in wind energy resources. According to the research of China Meteorological Administration Wind and Solar Energy Resources Assessment Centre, the potential wind power of China's 50 m onshore is 2.38 billion kW and the offshore wind power is 200 million kW.

China is abundant with solar energy and total quantity of radiation is roughly between 930 kW h/m^2/year and 2330 kW h/m^2/year. Daily average radiations are more than 4 kW h/m^2 in most areas and Tibet are up to 7 kW h/m^2. Total annual solar radiations are higher than 5000 MJ/m^2 and annual sunshine hours are more than 2000 h in China. The theoretical reserves reach 1.7 trillion tons coal equivalent each year. Generally, about two-thirds of China's areas are rich in solar resources, especially the regions of Qinghai–Tibet plateau, Xinjiang, Gansu, Inner Mongolia, who have good conditions to utilize solar energy.

From the above analysis, we can come to the conclusions: first of all, from the point of total resources, the resource of solar energy is rich with no limit, and it is easier to obtain, so the solar energy has obvious use advantage; second, from the point of developed degree of resources, all renewable energy resources have low developed degree and developing and utilizing renewable energy to generate power has good resources foundation and development potential.

3.1.2. Distribution

Biomass energy resources are abundant in China. According to resources, biomass energy can be divided into waste of agricultural, forestry, industrial, animal and sewage, and energy crops. The distribution of biomass energy in China is uneven and the differences between provinces are obvious. Calculated according to the rural population, biomass energy per person is the largest in Tibet Autonomous Region, with 14.17 t coal equivalent, while the least is only 0.15 t coal standard in Zhejiang Province (Table 2).

Wind energy resources in China are widely dispersed and the wind rich regions are mainly concentrated in the Southeastern coast, nearby islands and northern regions (north–east, north, north–west). In the inland, there are also some regions with abundant wind energy, for example, the offshore areas like Jiangsu Province (Table 3).

There are more than two-thirds areas in China with profuse solar resources. Especially in Qinghai–Tibet plateau, Xinjiang, Gansu and Inner Mongolia, solar energy is suitable for utilization. Based on the acceptable amount of solar radiation, China can be divided into four categories of regions, see Table 4.

Third, from the geographic distribution of solar energy resource in China, there is also a large deviation between solar

Table 1
Resources situation of China's renewable energy (GW).

Types	Reserves	Exploitable capacity/year	Explored capacity (installed capacity in 2010)
Biomass power	540	380	5
Wind power	Onshore: 2380 Offshore: 200	Onshore: 600–1000 Offshore: 150	31.31
Solar energy	–	100,000	0.40

《Renewable energy long-term development》, China meteorology department wind and solar energy resources evaluation center.
1 kg coal equivalent = 29.308 MJ, 1 KW h = 3.6 MJ.

Table 2
Physical reserves and distribution areas of biomass resources in China (2004).

Species	Reserve amount (million ton)	Districts
Straw	728	Henan, Shandong, Heilongjiang, Jilin, Sichuan
Animal soil	3,926	Henan, Shandong, Sichuan, Hebei, Hunan
Forestry biomass	2,175	Tibet, Sichuan, Yunnan, Heilongjiang, Inner Mongolia
Urban garbage	155	Guangdong, Shandong, Heilongjiang, Hubei, Jiangsu
Sewage	48,240	Guangdong, Jiangsu, Zhejiang, Shandong, Henan

Sources: Institute of Geographical Sciences and Natural Resources, Chinese Sciences Academy.

Table 3
Wind resources in seven 10-million kW wind power base.

Districts	Wind resources (250–300 W/m^2)/GW	Wind resources (300 W/m^2)/GW
Inner Mongolia	–	1300
Hami region in Xinjiang	–	250
Dam area in Hebei province	–	79.3
Jiuquan in Gansu province	–	210
Baicheng, Songyuan, Shuangliao in Jilin province	1100	15.4
Offshore of Jiangsu province(water depth of 5–25)	–	13.9
Inner Jiangsu province	3.4	–

Table 4
Distribution of solar energy resources in China.

	Daily radiation	**Region**
1	>5.1 KW h/m^2	Northern Ningxia, Northern Gansu, EasternXinjiang, Western Qinghai and Western Tibet
2	4.1–5.1 KW h/m^2	Northwestern Hebei, Northern Shanxi, SouthernInner Mongolia, Southern Ningxia, Central Gansu, Eastern Qinghai, Southeastern Tibet and Southern Xinjiang
3	3.3–4.1 KW h/m^2	Shandong, Henan, Southeastern Hebei, Southern Shanxi, Northern Xinjiang, Jilin, Liaoning, Yunnan, Northern Shaanxi, Southeastern Gansu, Southern Guangdong, Southern Fujian, Northern Jiangsu, Northern Anhui, and Southwestern Taiwan
4	<3.1 KW h/m^2	Hunan, Hubei, Guangxi, Jiangxi, Zhejiang, Northern Fujian, Northern Guangdong, Southern Shaanxi, Northern Jiangsu, Southern Anhui, Heilongjiang, Northeastern Taiwan, Sichuan, Guizhou

resources and electric load in Southeastern China and the grid construction is weak and the large-scale development requires support of grid extension.

In China, coal is mainly distributed in the north China, accounting for 64% of national reserves; oil major in the north-east, accounting for 40.3% of national reserves; water in the southwest, accounting for 71%.

From the above tables: First, to some extent, the distribution of biomass energy, wind and solar energy present a complementary state with the conventional energy, which shows the enormous potential to utilize renewable energy in the districts with less conventional energy reserves. Second, the geographical distribution of biomass energy resources does not match the electric power load; wind energy has two characteristics: one is that wind energy resource is poor in peak of summer, and rich in spring, autumn and winter, the other is that the geographical distribution of wind energy resources does not match the electric power load, that is to say coastal areas with barren wind energy have large electric power load and northern areas with rich wind energy have small load, which bring difficulties to the economic development of wind power; solar energy resources in southeast China also has big deviation with city power load, but in most areas the sun resources just overlap the peak load and its utilization can cut the power grid peak. Third, biomass, wind power and solar energy are distributed in the areas with weak power grid, which bring large difficult to the economic development, so the large-scale development of renewable energy needs the support of the power grid extension.

In conclusion, China has abundant biomass, wind and solar energy resources, but constrained by their distribution, large-scale development of renewable energy needs the support of the power grid construction. It is essential to develop UHV and ultrahigh power grid in China.

3.2. Industrial scale

Until 2010, the total installed capacity of wind power, solar PV and biomass power generation reached to 51,123 MW, among which the installed capacity of wind power generation was 44,730 MW, the installed capacity of biomass power generation was 5500 MW and the rest was PV generation. From Fig. 3 we know that the majority is wind power generation, accounting for 87.49% of the total installed capacity of renewable energy.

First, the installed capacity of biomass power generation had increased from 1400 MW in 2006 to 5500 MW in 2010, wind power generation had increased from 2555 MW to 44,730 MW and the PV generation had increased from 80 MW to 893 MW. Second, wind generation was always the main generation. In 2006, the proportion of wind power generation in total renewable energy generation was 63.32%, and in 2010 the number reached 87.49% (Fig. 4). Third, the growth rate of biomass and wind generation installed capacity had a declining trend, but the

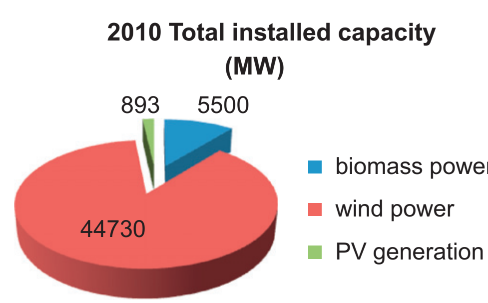


Fig. 3. 2010 China total installed capacity of new energy generation.

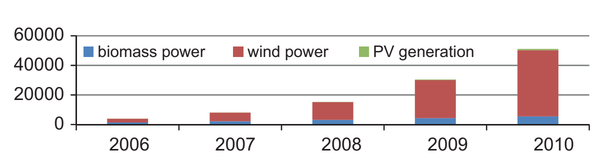


Fig. 4. Total installed capacity (MW).

growth rate of PV generation was rising which showed that solar PV power generation had increased fast (Fig. 5).

Analysis the above condition, we have following reasons: First, limited to the low technical level and collection, reservation and transportation caused by seasonal and rational distribution of biomass resources, profitability of biomass power enterprises reduce and the industry's growth rate fall down. Second, wind power generation grow slowing in recent years, one is because seasonal distribution of wind resources bring instability to wind power supply, which makes great impact to power grid, the other is lagging power grid infrastructure hinders the wind power development. Third, solar energy soared in the last few years. With the import of production line of sets of battery/component and amorphous silicon solar cells and the great demand in international market, the output of China solar modules rises sharply and localization process of equipment manufacturing and accessories production accelerated.

3.3. Market operation

3.3.1. Investors

In 2010, the investors of wind power generation were state-owned enterprises, private enterprises, foreign-funded enterprises and China–foreign joint venture, and the new installed capacity of these investors were 12.97 million kW, 0.63 million kW, 0.293 million kW and 1.537 million kW with the share of 84.0%, 4.1%, 1.9% and 10.0% (Fig. 6). Until now, major solar PV projects in China are supported by Chinese government, foreign governments and international agencies (Table 5). The implementation of these projects has made great contribution to development of China's sola PV market, improvement for China's solar PV technology, quality control of PV products and development of China's solar PV industry.

Until December 2009, five power generation groups (Datang group, Huaneng group, Huadian group, Guoneng group and China power investment group) were still the major investors and the projects which were put into operation had installed capacity of 939 thousand kW. The installed capacity of other state-owned companies, like China Guangdong Nuclear Power Group and Energy Saving Co., Ltd., was 562 thousand kW. Local power generation groups, like Shandong Luneng Power Group and Jiangsu Guoxin, had less installed capacity of 240 thousand kW. Under the support policies for biomass power generation, China's private enterprises and foreign capital gradually entered this field [1]. Wuhan Kaidi Holding Investment Co., Ltd. is a joint venture with Asia Green Energy Pte. Ltd and Prime Achieve Pte. Ltd. CLP Group, Hong Kong has invested in electricity market in mainland China from 1985 and is the largest foreign investor (Fig. 7).

China's renewable energy market is becoming more open. The main investors of China's renewable energy are state-owned enterprises, private enterprises and foreign capital, etc. And the approaches which foreign capitals enter to Chinese renewable power generation market are diversity: solar energy industry attracts equipment investment, biomass power generation is main in the form of China–foreign joint venture, and foreign capitals mainly invest in China's wind power equipment manufacturing department.

3.3.2. Equipment and grid feed in situation

Table 6 shows equipment and grid feed-in situation off wind, biomass and solar PV generation in China. In addition, China actively develops smart grid which regard UHV power network as the backbone grids and grids at all levels coordinate. Unified smart grid has the features of information technology, digitization, automation and interaction.

China's smart grid will be implemented in three phases and will fully complete uniform "strong–smart grid" by 2020. Planning pilot phase is from 2009 to 2010, focusing on planning processes for "strong–smart grid" development, making technology and management standards, starting technology and equipment research and development, as well as the link pilot project.

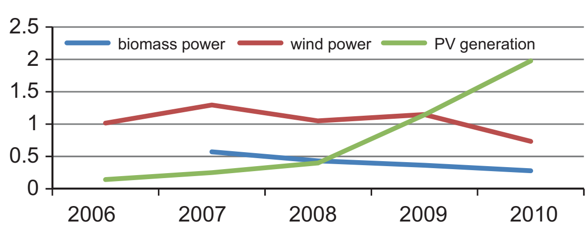


Fig. 5. The growth rate of installed capacity (%).

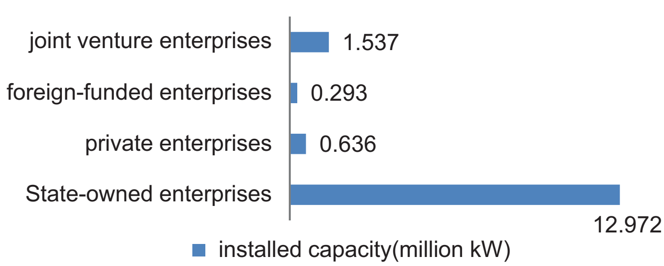


Fig. 6. Constitute of wind power in 2010.

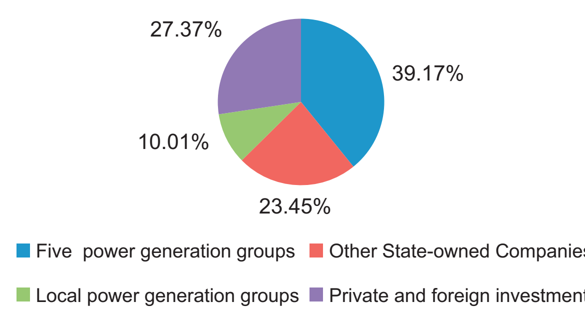


Fig. 7. Composition of biomass power generation investors.

Table 5
Major solar PV projects in China.

Projects	Investors	Projects	Investors
"Bright project" pilot project	National development and Reform Commission, local government	Germany KFW project	Germany Government
"Transmission" project	State Development Planning Commission, local government	Germany GTZ project	Germany Government
New energy plan in Inner Mongolia	Inner Mongolia Autonomous Regional Government	Canada solar project	Canada Government
World Bank, GEF REDP program	Global Environment Fund	Japan NEDO project	Japan Government
Silk Road lighting plan	Netherlands Government		

KFW: China–German cooperation Western solar project.
GTZ: China–German technical cooperation in the application of renewable energy projects for improving opportunities for local development in rural areas.

Table 6
Equipment and grid feed-in situation of renewable energy in China.

	Wind power	Biomass power	Solar PV
Equipment situation	Do not have the ability to produce large wind power generators and 80% of the devices need be imported. Cost of wind power is 33%–60% higher than coal electricity.	Limited to resources, unequal distribution leads to higher costs. It is complex for collection, storage and transportation of agriculture and forestry waste. Related scientific research, technology and talent support are not enough and research and development lag in enterprises development.	90% above materials and markets are dependent on foreign market. Key equipments are also import-based facilities, which lead to low industry profits.
Grid feed-in situation	Wind energy are distributed in the western regions, while power users are distributed primarily in the eastern coastal and wind power transmission costs are higher.Wind power development significantly exceeds expected and power system planning and construction speed is far less than the speed of wind power development, which lead to barriers for grid feed-in of large-scale wind power.	The electricity quantity of renewable energy projects should be bought entirely by grid enterprises within their network coverage and the grid feed-in service should be provided for renewable energy power generation in order to solve the grid feed-in issues.	PV industry is mainly used in remote areas and market is small for lack of overall arrangements. Grid feed-in PV power projects are individually allowed to connect the grid.

Table 7
Current technology of biomass, wind and solar PV power generation.

	Biomass	Wind power	Solar PV
Basic research	Biomass power plant integrated automation system with independent intellectual property rights;	Testing and certificating organization; China first wind power forecasting systems; MW wind turbine and wind control system;	Simulating and modeling for solar PV grid-connected system; Simulation research of PV plant operation control technology; Simulation model for grid feed-in PV power station;
Generation technology	Automation technology of biomass power plants, application technology of collection, storage and transportation equipment, biomass power plant operation optimization technology, biomass power generation ash compound fertilizer technologies, briquette technologies;	Solve grid feed-in problems of small-scale and medium-scale wind power plants; Complete the study for 2 MW and 3 MW double feed/ straight-drive converter prototype and 2 MW unit three axis independent electric variable oar system prototype;	Construction of hundred KW-level city building PV power stations and the research of grid feed-in technologies for ground PV power station.

Building phase is from 2011 to 2015, which need speeding up construction of UHV grid and rural or urban distribution network and initial formation of smart grid operation control and interactive service system and achieving major breakthroughs and broad application of key technology and equipments. Leading–promotion stage is from 2016 to 2020, with completed uniform "strong-smart grid" and technology and equipment of international advanced level.

China power grid construction lags. Accumulative investment in China electric power industry is 6.9 trillion yuan, including 2.68 trillion yuan in power grid, which is far lower than the international average of 50–60%. The low investment brings high pressure to EHV and distribution network and leads to large-scale, long distance and high efficiency hydropower grid construction lagging from energy base to the center of the load. Power grid construction lags also effect country's wind power development and lead to the status of high installment capacity with low generation capacity in China wind power. And power grid problems also restrict the development of China photovoltaic power generation.

3.4. *Profitability*

During "Eleventh-Five Year Plan" period, China had made important progress in the fields of basic research and power technologies in renewable energy power generation (Table 7). First, in basic research, China carried out research of wind power forecasting, wind turbines and power plant control system, established wind power testing and certification organization, implemented simulating and modeling for solar PV grid-connected system and studied integrated automation system of biomass. Second, as for generation technologies, China had resolved automation technology of biomass power plants and application technology of collection, storage and transportation equipment; for wind power, China had completed the study for 2 MW and 3 MW double feed or straight-drive converter prototype and 2 MW unit three axis independent electric variable oar system prototype, and meanwhile had resolved grid feed-in problem of small-scale and medium-scale wind power plant, and carried out construction of hundred KW-level city building PV power station and the research for ground PV power station grid feed-in technologies. Conclusions can be drawn that only wind power established testing and certificating organization and solved grid feed-in problems of small-scale and medium-scale wind power plants. Biomass and solar power generation still have larger network problems and lacked the necessary testing and certificating organization to protect.

Based on China's renewable power generation technologies and their raw material cost as well as price level, costs of China's

renewable energy power generation are shown in the following Table 8. The cost of wind power generation is the lowest, which is $0.0773–0.1005 per kW h, and the next is biomass power generation with $0.0618–0.1546 per kW h and the highest cost is solar power, whose cost is between $0.1546 and 0.2319 per kW h and solar thermal power generation cost is more than $0.3092 per kW h. And all costs of the renewable power generation are higher than thermal power grid tariff in Xinjiang and Guang Dong.

For a more intuitive understanding of the profitability of renewable power generation, a few typical manufacturers (Table 9) are selected. Guangdong Chant Group Ltd is a main group of biomass power generation. Suntech Power Holdings Co. is a high-tech PV enterprise and has become one of the most important manufacturers in international solar PV industry. Huarui Wind Power Technology Corporation is China's first wind enterprise who independently develop, design, manufacture and sell wind turbines which can adapt to varying wind resources and environmental conditions of large terrestrial, marine and inter-tidal. Guangdong Chant Group Co Ltd has the largest profit margin, followed by Huarui Wind Power Group Ltd, and the profit margin of Suntech Power Holding Co. is lowest. It can be concluded that both biomass power enterprises and wind power enterprises can get better returns, while the revenues of solar PV enterprises are lower compared to the other generations Table 10.

Table 8
Costs of different kinds of electricity.

Generation	Cost ($/(kW h))	Generation	Cost ($/(kW h))
Thermal power grid tariff (Xin Jiang)	0.0356	PV generation	0.1546–0.2319
Thermal power grid tariff (Guang Dong)	0.0727	Solar thermal power	0.3092
Wind power	0.0773–0.1005	Biomass power	0.0618–0.1546

Resources: Energy research institute of national development and reform commission.
Note: $1 = 6.4685 RMB (according to the exchange rate on July 1st, 2011).

Table 9
Typical renewable energy manufacturer's earnings ($ million).

Company	Main business		2008	2009	2010
Guangdong Chant Group Co.,	Waste incineration power generation	Income	1.014	1.006	1.072
		Cost	0.600	0.553	0.582
		Profit rate	0.690	0.819	0.842
Huarui Wind Power Group Ltd	Wind power	Income	796.558	2122.64	3142.13
		Cost	699.354	1,791.44	2,651.59
		Profit rate	0.139	0.185	0.185
Suntech Power Holdings Co.	Solar PV	Income	1923.50	1693.34	2901.90
		Cost	1580.60	1354.58	2398.09
		Profit rate	0.217	0.250	0.210

Table 10
Policy support for renewable energy.

	Tax preferential	**Fee waiver**	**Financial subsidies**	**Concessional loans**	**Special funds**
Renewable energy	1 Renewable Energy Law 2 Development Guidance Directory of Renewable Energy Industry 3 National medium- and long-term science and technology development program (2006–2020)	1 Temporary measures for Revenue allocation of addition price on electricity of renewable energy resource 2 Interim management measures for renewable power tariff and cost allocation 3 National medium-and long-term science and technology development program (2006–2020)	1 Interim measures on renewable power surcharge collection and allocation 2 Notice on scheme for renewable power tariff subsidies and quota trading 3 Development Guidance Directory of Renewable Energy Industry 4 National medium- and long-term science and technology development program (2006–2020)	1 National medium- and long-term science and technology development program (2006–2020)	1 National medium- and long-term science and technology development program (2006–2020) 2 Interim measures on renewable energy special fund management
Biomass power	Policies notice about comprehensive utilization of resources and the VAT of other products Circular Economy Promotion Law		Temporary measures for management of subsidy fund of utilizing straw energy resources		Circular Economy Promotion Law
Wind power	Policies notice about comprehensive utilization of resources and the VAT of other products	Notice on improving wind power grid tariff policy			Interim measures for earlier management of wind farm project
Solar power			Interim measures on administration of financial subsidies for application of solar energy photovoltaic building		Interim measures on management of fiscal subsidy funds for Golden Sun demonstration project

In Table 9, we can see that biomass power generation enterprises can get higher profit rate than solar PV enterprises and the wind power company has the lowest profit rate. Meanwhile, comparing to the steady growth profit rate of wind power enterprise, biomass and solar power generation have fluctuant profit rate. The cost of biomass raw materials rises in recent years. Production and application market of PV industry break away and the cost of PV generation is too high. However, since March 2011, the prices of components, battery, silicon wafer has fallen more than 40% and price of polycrystalline silicon has dropped over 30%. As the costs of PV generation falling, enterprise's profit rate and the ability to resist risk get improved Table 11.

3.5. Policies

3.5.1. Policy situation

The implementation of Renewable Energy Law has established the legal support for the development of renewable energy, and the 10 sets of rules and the relevant management measures of special funds supporting Renewable Energy Law have been implemented followed, which promote the rapid development of renewable energy generation in China. Introductions of industry policies, such as taxes, fee waivers, financial subsidies, concessional loans and special funds are as follows. In addition, grid enterprises should make agreements with renewable power generation enterprises, who have legally obtained administrative licenses or sign the electricity purchasing agreement with power generation enterprises of renewable energy which are put into records. The electricity quantity of renewable energy projects should be bought entirely by grid enterprises within their network coverage and the grid feed-in service should also be provided in order to solve their grid feed-in issues. According to the distance of line, the subsidies for grid feed-in projects are different with $1.55 per 1000 kW h for distance within 50 km, $3.09 per 1000 kW h between 50 km and 100 km and $4.64 per 1000 kW h equal and above 100 km. In order to support the research and development for technology and industrialization of renewable energy, government has implemented some science and technology programs, such as "863 programs", "973 programs" and other industrialization plans [2].

During "12th five-year plan", China will implement renewable portfolio standards. "we will continue to enact and perfect renewable energy policy design, especially renewable portfolio standards", said Shi Lishan, chief of National energy bureau new energy company.

Renewable portfolio standard not only solves problems of power generation, grid feed-in and market absorption from demand side, but also improves industry scale development degree and market concentration and help to establish the competitive industry system. But concerning the specific goals, implementation method and quota effect of this policy, great uncertainty still exist. Therefore, renewable energy policy in China need more concern in the future.

3.5.2. Government planning

According to China's "12th five-year plan", the share of non-fossil energy consumption will be 11.4% of that of primary energy until 2015. In order to achieve this goal, renewable power generation will reach 250 billion–270 billion kW h by 2015. In the plan, onshore wind power is the main renewable energy generation with installed capacity of 95 GW and followed by biomass power generation with installed capacity of 13 GW, and the installed capacity of solar energy will reach 10 GW (Table 12).

First, installed capacity of China's wind power will reach around 100 million kW by 2015, among which onshore wind power and offshore wind power are 95 GW and 5 GW; solar energy has the installed capacity of 10 GW with 9 GW for solar PV and 1 GW for solar thermal power generation; installed capacity of biomass power generation is up to 13 GW. From the aspect of installed capacity, wind power is still the mainstream in the future, the installed capacity of which is seven times larger than

Table 12
Renewable power generation target in China's "12th five-year plan"".

Renewable energy generation	Installed capacity (GW)	The ratio in the all energy (%)	Generating capacity (billion kW h)	The ratio in the all energy (%)
Wind power	100	7.1	190	3.1
Onshore wind power	95	6.8	180	3.0
Offshore wind power	5	0.4	10	0.1
Solar energy	10	0.7	14	0.2
PV generation	9	0.6	12.6	0.2
Solar thermal power generation	1	0.1	1.4	0.0
Biomass power	13	0.9	52	0.9
Total	123	8.8	256	4.2

Table 11
Tax incentives, financial subsidies and network security for renewable energy.

	Tax incentives	Financial subsidies	Network security	Price support
Biomass power	**VAT:** Instant levy and instant refund for waste power generation **Income tax**: First three years free, next three years half	Establishing relevant special fund for circular economy to comprehensively utilize crop straw and biogas. Enterprises majored in straw briquette, straw gasification and straw carbonization etc. are given comprehensive subsidies by central finance.	Full acquisition by government	Feed-in law
Wind power	**VAT**: Half **Income tax:** First three years free, next three years half	Former 50 MW-level wind turbines in enterprises meeting support requirements are supplemented of $92.76/kW. Machine manufacturers and the manufacturers of main components both get 50% and subsidies are mainly used for new product development.	Full acquisition by government	According to resources, four types of Benchmarking electricity price: 0.51, 0.54, 0.58, 0.61
Solar power	–	Arrange certain funds from renewable energy special funds to support solar PV technology study and the PV applications in the field of urban and rural demonstration construction.	PV power projects are individually allowed to connect the grid.	Large photovoltaic: examination and approval and franchise bidding pricing Small and medium: initial investment subsidies, solar energy building demonstration project etc.

that of biomass power generation, but solar power is still 30% less than biomass power. Second, in 2015, generation capacity of China's wind power is expected to reach 190 billion kW h, which is over twelve times larger than that of solar generation (14 billion kW h) and three times of biomass power generation (52 billion kW h). From the perspective of electricity production, wind power ranks first, followed by biomass and solar energy. Third, from the above data we know that biomass has the maximal machine utilization hours, followed by wind power and solar energy. It can be concluded that equipment utilization of biomass power generation is much higher compared to other two kinds of generations.

4. Prospects and risk

4.1. Prospects

China has abundant wind, biomass and solar energy resources which guarantees large-scale development of renewable energy generation. The distribution of renewable energy presents a complementary state with the conventional energy, which shows the enormous potential to utilize renewable energy in the districts with less conventional energy reserves. However, there is large deviation between the distribution of resources and electric load, raising new challenges for the development of renewable energy. So the large-scale development of renewable energy in China needs the support of grid extension.

For industrial scale, among the existing renewable energy generation, wind power has the largest industrial scale, followed by biomass power, and the scale of solar PV generation is the smallest. Limited to technical level and resources, biomass power growth rate falls down. Wind power generation has finished its soaring growth time and turns into steady growth. With the import of production line of sets of battery/component and amorphous silicon solar cells and the great demand in international market, solar energy soared in the last few years. Along with prices of solar PV generation components falling down and technological progress, PV power generation is still the most promising industry of China. In 2010, China imported 43,000 t of polysilicon and domestic demand–supply gap is still large, therefore, domestic PV market will be main market.

For market operation, the state-owned enterprises are still the main investors in wind power and biomass power generation market and private enterprises and foreign capital gradually enter into this field. While major solar PV projects in China are supported by Chinese government, foreign governments and international agencies. There still exist weak and lagging grid construction problems for renewable energy. Along with China's smart grid project construction, China power grid problems are expected to ease and China's wind power and solar power industry will get rapidly development. For low grid tariff and lagging technology, except wind power could get certain profit, more enterprises are still in the situation of small profit or even loss. But there are still investors in renewable energy with high technology level having better revenue.

And since the implementation of Renewable Energy Law in January 2006, Chinese government has raised the price of coal-fired power repeatedly. Meanwhile, the cost of renewable energy power generation falls down and the cost difference of renewable energy and coal-fired power will be narrowed. Renewable energy industry profits will gradually expand.

For policy environment, in order to promote renewable energy development, Chinese government has implemented a series of support policies, including financial allowance, preferential tax, fee waiver, concessional loans and special funds to support renewable energy. But there are rarely supports for solar photovoltaic power generation and electricity grid is not responsible for grid feed-in of solar PV. During "12th five-year plan", Chinese government will implement renewable portfolio standards and the investment chance bringing about by this policy needs more attention.

Table 13
Installed capacity potential of renewable energy (MW).

	Wind power	Solar energy	Biomass power
2010	44,730	893	5,500
2015	100,000	10,000	13,000
2020	160,000	24,000	15,000

Table 13 shows the installed capacity potential of renewable energy in 2015 and 2020. Comparing to wind 2020 target of 160 million kW, domestic market can only support around 13% growth rate one year. Limited to the uncertainly support policy, installed capacity of biomass power generation in government 2020 planning only expansion less than two times, therefore its development potential is limited. PV power installed capacity will soar nearly 26 times to the year 2020 and PV power generation is the most promising industry in renewable energy industries.

4.2. Risk

4.2.1. Competitive risk

First, large manufacturers of wind power have good development prospects. Due to the higher technical barriers in wind power equipment industry, other businesses are unable to enter the wind power industry in the near future. Second, small wind power manufacturing enterprises will face fierce competition in the market. Wind power generators of these enterprises are still at prototype functioning or small batch production stage and domestic "49.5 MW wind plant" is their main living space. Therefore, this market competition pattern will not be long sustained and wind power industry will inevitably concentrate.

Most biomass power projects are small and their capital intensives are less than other renewable energy. Taking account of distributed funds and management difficulties, large groups and scaled investors should invest carefully. Meanwhile, investments in most of medium and small biomass power projects are about several millions and tens of millions RMB. The funds' scale bring about considerable pressure to most medium and small companies, especially biomass power technologies are mostly used in rural areas, which leads heavy financial burden for the local enterprises.

Import-based devices, uncoordinated industry and small market scales are bottlenecks for the development of solar energy industry. More than 90% of raw materials and markets are dependent on foreign market and key equipment relies on imports. And the requirements for solar product technology development are relatively high. Both bias in understanding and border in technological process and quality will affect the yield and investment return period. The large upfront investment increase financial risks. Less comparability for markets products leads to the necessity to guide consumers.

4.2.2. Policy risk

There are still problems of high cost and low competition in wind power generation and its development needs supports from national policies. If the existing preferential policy cannot be sustainable, or related policies are instable, investment risk in wind power will increase and less enthusiasm in wind power

investment directly leads to reduction in demand for wind power equipments. In addition, in order to encourage domestic development of wind power equipment manufacturing industry, government put forward the requirements for equipments: wind power equipment localization rate must be over 70% and the construction of wind farm which does not meet this requirement is not allowed. And new regulations in 2006 require binding bid of wind power operator and device manufacturers to guarantee the 70% localization rate and operator is not permitted to choose another device manufacturer after successful tendered.

First, existing biomass grid feed-in tariff is provided by National Development and Reform Commission, which regulates that new agriculture and forestry biomass power projects, not tenders to determine investor's, uniformly implement benchmark pricing of $ 0.75/kW h (including tax). While the cost of biomass power generation is related to the local biomass fuels market, the price of labor, the habit of farmers' production and living etc., which lead to the high cost of biomass power generation. Second, price subsidies for transmission investment as well as operation and maintenance cost of biomass power grid feed-in projects are made according to the length of the lines. Third, the benchmark electricity prices for coal-fired units in different regions are varying. While the electricity price subsidy is fixed which results in the regional differences of electricity prices. Mean while, different technologies of biomass power generation lead to the different costs and earnings. Therefore, the uniform subsidy to different types of biomass power generation technology is not beneficial to the diversified development of technology of biomass power generation [3].

Nowadays, China lacks preferential policies and subsidies which can be actually operated for solar power generation. Power department also does not have explicit approval for solar PV power generation connecting grid and the grid feed-in PV power generation systems which have built are allowed by Power department one by one. And most solar PV generation are made for plants themselves. Power department does not pay this electricity. To sum up, in spite of the principle affirm and support on solar PV generation from State, solar PV is virtually impossible to promote large-scale development and relevant policies need to be further improved.

4.2.3. Technique risk

Nowadays, China has the ability to product 2 MW wind turbine while independent research and development capability of large wind turbine is weak. There exists a big supply–demand gap for above MW core parts and manufacturers are still at technology import-absorption stage and have not yet formed their own key technology. There is no machine technology and it needs to make technology breakthroughs in accepting bulk wind power. In addition, the benefit-sharing conflicts with general electricity are not resolved. Wind power industry service system is not yet perfect for lack of talent cultivation system for design, manufacture, installation, commissioning and operation management of wind power industry and insufficient research and development as well as management personnel. Therefore, the development of wind power industry in the future faces greater risks.

First, China lacks design, manufacturing capacity and using experience for the special boiler which is used to fire the waste of agricultural crop and forestry and also lacks technical personnel; the equipments needed for raw materials storage and transportation cannot meet the demand. Second, the domestic research support is still insufficient and some researches of soft science relevant to biomass power generation develop slowly. For example, the system of standard and regulation has not been established yet [4].

Solar power is an emerging industry and countries all over the world increase scientific input for research and development, which lead to the emerging of new products and new technologies. However, life cycles of solar energy-related products are getting shorter. And if businesses have slow update rate, the product will soon be eliminated by the market.

5. Conclusions

Through the above analysis, this paper gets the following conclusions:

Although there are still existing some problems like low technical level and uncertainty policies, China wind, biomass and PV power generation have the condition to scale development and function well in improving energy structure and reducing greenhouse gas emissions.

First, under the guidance of "12th five-year plan" and renewable portfolio standards, biomass power generation has a good prospect. Second, the wind resource properties determine that its scale development needs power grid support; and with the construction of intelligent power grid, wind power continues on its steady development way. Third, with solar energy components price falling down, the bottleneck which restricted solar power generation development gets eased; meanwhile, in the government "12th five-year plan", solar power generation is more emphasized, therefore, solar energy generation is the industry of most potential. Fourth, wind power and photovoltaic power generation have more advantages in industrialization, resources and economy.

Exert complementarities of solar and wind energy in geography and resources and construct wind–light complementary system. Wind power and solar power have some complementarities in generating phase, therefore combining them is good to smooth their output curve and reduce the impact to power network and reduce requirements of peaking plant.

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